Printing versus coating technology – Which way Printed Electronics with solution coating will go?

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1. ABSTRACT

The market of Large Area Organic Printed Electronics is increasing rapidly. The target is to develop efficient and qualitative as well as devices with lower cost. Applications for OPV, OLED, RFID and compact printed electronic systems are winning on importance. Products which can be produced with printing and coating processes are for instance:

- Phosphorescent layers,
- Labels with information transfer,
- Electro luminescent layers,
- Foldable electronic magazines and displays,
- Bighting wall paper,
- Printed boards,
- Organic solar cells,
- Printed batteries,
- RFID-antenna and
- Printed sensors

Roll to Roll (R2R) processes are used to make final products more affordable but at the same time highly accurate. There are numerous printing and coating technologies suitable depending on the design, the product application and the chemical process technology. Mainly the product design (size, pattern, repeatability) defines the application technology. With the presentation we will show the different coating and printing methods as well as machinery layouts for the production of printed electronic devices by wet coating processes.

2. CLEAN TECHNOLOGIES

Products for environmental protection, energy saving and energy production are increasing. Samples for products which are produced on the field of green technologies are:

- Epoxy resin coating processes and impregnation of glass, carbon and synthetic fiber for light construction materials,
- Coating processes for anodes, cathodes and separator films for lithium ionic batteries,
- Coating processes of anode, cathode and membranes for fuel cells,
- Production of barrier films and lamination of backsheets for flexible solar cells,
- Coating and printing processes for organic and printed electronics,
- Coating and printing processes for OPV, OLED, RFID technology,
- Nano layers < 50 nm on flexible materials and last but not least
- Membranes for water treatment and salt water desalination.

3. COATING AND PRINTING PROCESSES

Often it is difficult to make a clear differentiation between necessary coating and printing processes for the described products because different designs can be realized with various technologies. A clear definition of the product design determines the choice of the right application technology. Each technology like slot die, direct- and flexo-printing, screen and ink jet printing has advantages and disadvantages in use and are mainly chosen depending on viscosity and requested coating thickness and coating design. Generally, high performance application processes are necessary. For wet solution coating processes of Printed Electronics, defect-free coating is required together with the following requirements:

- Cross-Web Distribution with less than +/-1% deviation,
- Wet coating thickness less than 1 µm, dry less than 100 nm,
- Coating thickness must remain constant over 24h of production,
- Printing texture with highest resolution.

3.2 Requirements for precise coating and printing processes

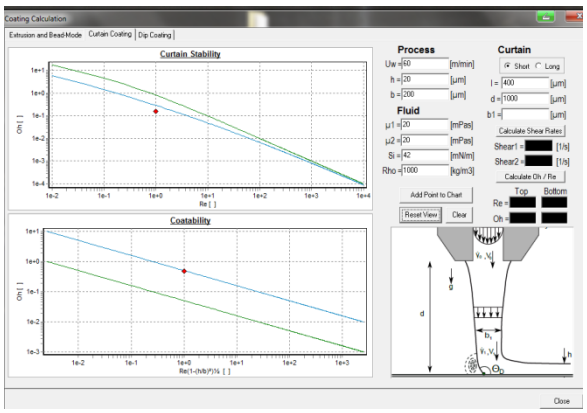
Generally, the coating technologies are divided into self-metered and pre-metered coating techniques:

1. Self-metered-coating means the applied coating weight depends on the process. With dip-coating processes the speed of substrate defines the coating thickness, in case of roller-coating the speed of the roller and the gap between the rollers defines the coating thickness. For comma bar coating the gap between the comma bar and the substrate determines the coating thickness.
2. Pre-Metered-Coating means the applied coating weight does not depend on the process, e.g. slot-die-coating and spray-coating. With such technologies the pumping speed of the dosing system is the main influencing factor for the coating thickness.

Slot die technologies are characterized by capillary forces, which are acting between the slot-die respectively the slurry which is coming out of the die and the substrate. The distance between slot die and substrate is often less than 200 µm. A very low wet film thickness (~ 1µm) is possible at substrate speeds of less than 50 m/min. The distance from the slot die to the substrate can be 300 times the coated wet film thickness. Different slot die settings are defined by the gap between the slot-die and the substrate:

Picture 1: Definition of slot-die technique depending on distance (d) between slot-die and substrate

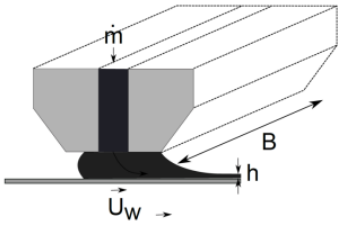
The coating window for a slot die operating in the short-curtain-coating-mode can be calculated in order to support the coating on the coating facility as well as to safe expensive chemistry. If the coating operation slot is calculated outside of the coating window it is not useful to start the coating process.



Picture 2: Calculation of the coating window for slot-die application

The calculation of coating windows helps to control the process. The following parameters are important:

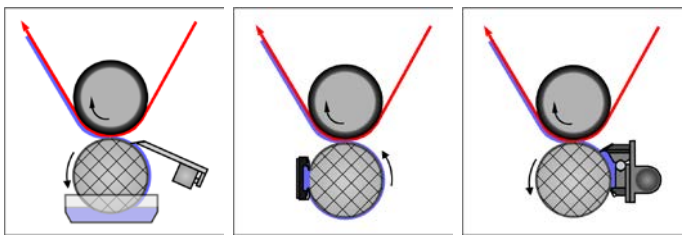
- Fluid parameters (viscosity, surface tension)
- Process parameters (distance between slot die and substrate, wet film thickness, substrate velocity)
- Lip length of the slot-die



Picture 3: Definition of slot-die coating process

It is possible to define the flowing behaviour through the slot-die by knowing the coating liquid density, the working width, the gap between the slot-die and substrate speed with the equation $\dot{m} = \rho \cdot U_w \cdot h \cdot B$. In this equation m describes the mass flow, U_w the substrate velocity, B the coating width, h the wet film thickness and p the density of the coating slurry.

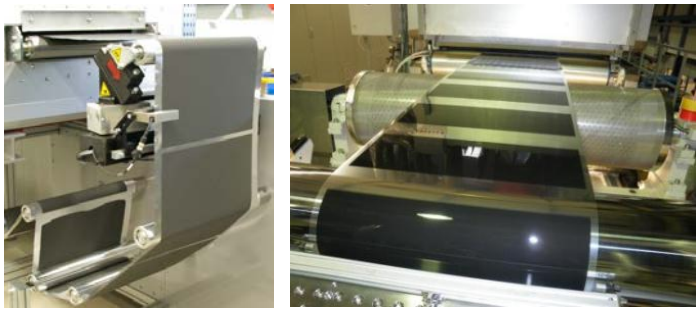
Roller technologies can be used for printing as well as coating processes. In case of printing procedures, the application roller is in contact with the substrate. During coating procedures the process can be contact- less or with contact. The supply of the coating chemistry to the applicator roller can be realised with different technologies like conventional gravure printing knife with oscillation [1], T-chamber for gravure printing and coating in direct and reverse mode possible [2] and gravure printing pan less pressure chamber system for direct coating and printing MG 300 [3].



Picture 4: Design of dosing systems for roller application systems [1 to 3 from left to right]

3.2 Intermittent coating operation processes

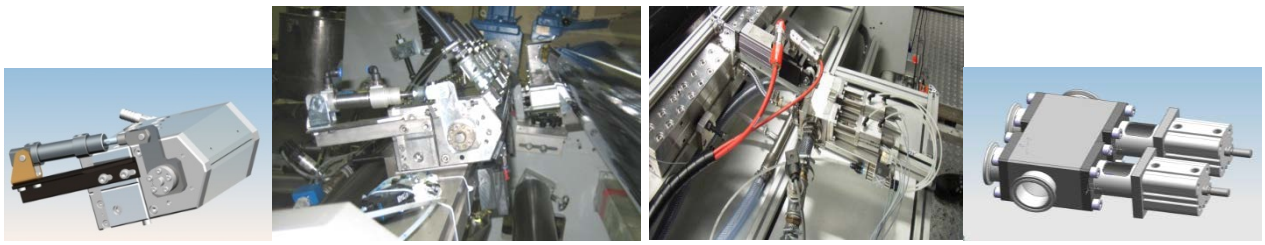
For many applications it is necessary to apply an intermittent design of the coating layer. For instance, intermittent coating applications are used for battery electrodes for lithium ion batteries. The intermittent design of the coating layer is requested for two different reasons, the design of the batteries as well as to improve the calendar process. Intermittent coating applications are possible with slot-dies, rollers and comma bar coating technologies.



Picture 5: Intermittent application with commabar and alternatively with slot–die technology

KROENERT offers two different intermittent slot-die coating processes for the production of battery electrodes. The chosen technology depends on the rheological and visco-elastic behaviour of the battery slurries. We define between a rotating bar in the slot die and a valve in front of the die. With both technologies it is possible to start and stop the slurry flow through the die on to the substrate.

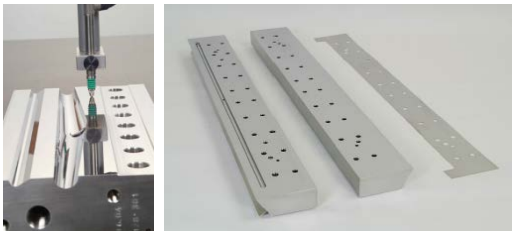
The patented rotating bar technology is defined by a slitted rod, which means in between the two die plates is fixed a rod with a slit in the centre. This bar is oscillating and with this the coating flow through the die can be started and stopped. Alternatively the start and stop of the coating slurry through the die can be realised with a valve technology in front of the die.



Picture 6: Intermittent coating with rotating bar in slot-die versus valve technology in front of slot-die

With the accuracy of slot-dies the accuracy of the coating layer can be influenced. Different qualities are suitable.

Quality	Tolerances 1st Slot	Tolerances 2nd Slot
AAAA	± 0.5 µm	± 0.25 µm
AAA	± 1.0 µm	± 0.50 µm
AA	± 2.0 µm	± 1.00 µm
A	± 4.0 µm	± 2.50 µm
B	± 6.0 µm	± 6.00 µm



Picture 7: Slot-die qualities and measurement of the quality

It is possible to reach the following parameters with slot-die coating processes.

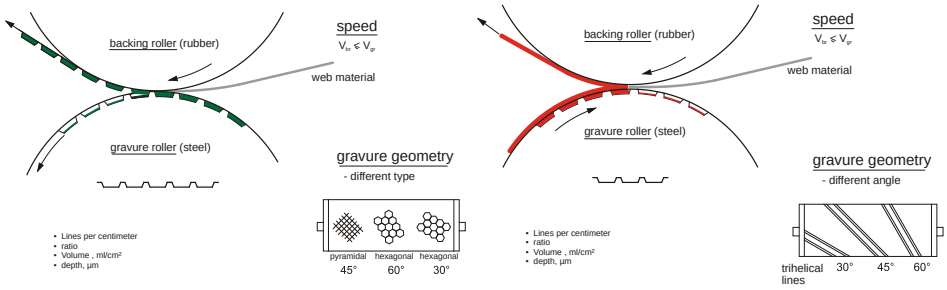
- Angle adjustment suitable range between +/- 5 °
- Gap adjustment between slot die and substrate 0,5 µm steps
- Running precision coating roller 1 µm
- Running precision measurement roller 1 µm
- Running precision guiding roller 5 µm
- Precision of speed adjustment +/- 1 %
- Tension adjustment of substrate +/- 1 N

3.3 Roller technology for coating as well as printing processes

The advantage of roller technologies is the flexibility of the technology. Depending on the running direction of the application roller and the design of the roller it is possible to achieve coating and printing processes with one application equipment.

Printing technologies are possible with

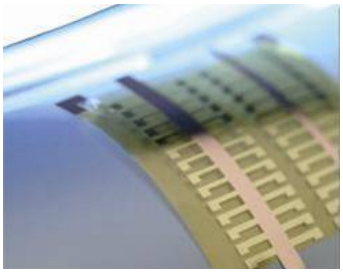
- Engraving for min 2 pt textures,
- Hexagonal cell engraving,
- All kinds of line-engraving as well as
- Structures engraving.



Picture 8: Printing versus coating with roller application technologies

For printing applications, a gravure design with highest resolution is required. Hexagonal cell and engraving structures are used for printing processes. The application roller is always running in the same direction then the substrate. In case of coating applications, all kinds of line-engraving as well as defined gravure designs can be used. The application roller can be adjusted in direct or reverse direction to the substrate direction.

Alternatively, the indirect or flexo printing technology is used for printing applications. An engraved roller is supplied with the coating media from a chamber system or pan and transfers the media to the flexo roller in a relief printing process.



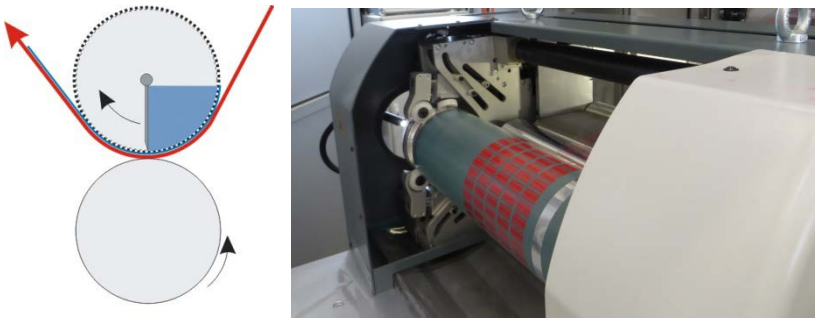
Picture 9: Printing processes with flexo-printing cylinders

Laser engraved flexo printing sleeves are characterized by:

- Laser engraving with a minimum of 2 pt texture and with highest resolution,
- Hexagonal cell engraving,
- All kinds of line-engraving as well as
- Structured engraving.

3.4 Rotary screen technology

Rotary screen technologies are used for printing processes as well. This technology is used mainly for thicker lines and designs for instance to interconnect solar-cells.



Picture 10: Rotary screen printing technology

A very interesting technology for roll-to-roll printing processes will be the ink-jet printing technology. KROENERT has already started to evaluate this technology and works with selected partners.

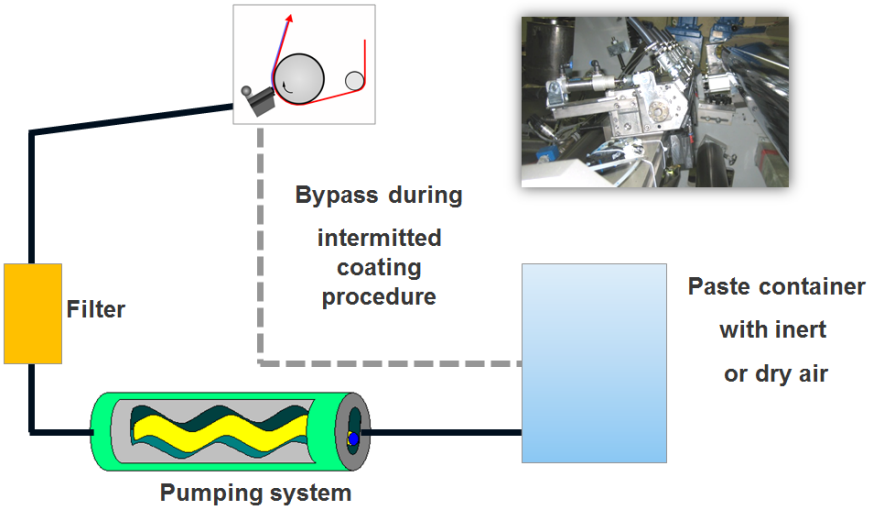
With modern printing and coating technologies like gravure, slot-die and flexo-printing it is possible to guarantee at least the following parameters:

- Coating-Weight (wet): 0,8 µm up to 500 µm
- Coating Tolerances: +/- 5% (MD and TD)
- Machine Speed: 0,1 up to 100 m/min
- Register (longitudinal): +/- 0,02 mm
- Register (lateral) +/- 0,02 mm
- Register (double sided): +/- 0,50 mm

3.5 Slurry supply to the coating equipment

The coating chemistry for organic and printed electronic is very often available only in a small volume as well as very expensive. It is necessary to supply the coating chemistry to the process with a very low volume.

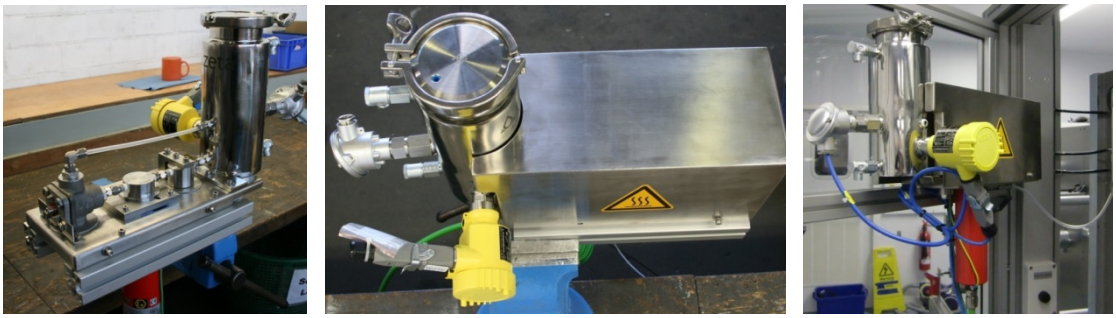
For accurate coating processes it is also necessary to realise a precise paste supply to the die including a fine filter system to guarantee a constant coating slurry quality.



Picture 11: Overview of the complex paste supply system during intermitted coating procedures

For slot die application processes precise paste supply systems were developed which includes the following units:

- Double walled tank (1 liter),
- Fully temperable which means suitable for a constant temperature,
- Stirrer,
- Level-sensor,
- Filter and
- Micro-pump.



Picture 12: Developments for small coating slurry volume

4. COATING LINE CONCEPTS

For many products it is necessary to apply more than one layer over each other. For such precise layer over layer application modern coating and printing lines are equipped with register control for precise application of the different functional layers. A multi-head coating line is a typical example of a state-of-the-art coating line. To produce organic PV with solution coating processes an ITO-coated substrate is the base material for coating. The first coating head applies the photoactive layer (very often P3HT:PCBM) the second head lays down the electron conductive layer, mainly PEDOT:PSS and the third printing head deposits the silver grid as interconnection.

Picture 13: Roll to roll coating multi-head line for organic solar cell production

Today, it is necessary for machine manufacturers to demonstrate and to test different process technologies. With their own Technology Centre, KROENERT offers the possibility to test different printing and coating processes together with different drying and curing technologies. KROENERT is able to demonstrate all suitable technologies for innovative leading edge products for the Printed Electronics market.

5. CONCLUSION

Today it is necessary to demonstrate coating and printing processes with test runs. KROENERT is using different coating lines in his Technology Center to support customer activities.

Purpose for our customers:

- Test runs under production conditions with various coating methods,
- Process optimization and
- Process development.

Purpose for KROENERT:

- Optimization of existing processes and development of new technologies,
- Determination of guaranteed process specifications and
- Development of process expertise (from know-how to know-why).

Picture 14: Versatile coating lines in the KROENERT Technology Center

The presentation will give an overview of the state-of-the-art high-end printing and coating techniques and processes in the Printed Electronics market. In all cases of Printed Electronics, customized machine solutions and processes are required, based on standardized advanced technology machine components.